Status and Perspective of the

High Intensity Heavy-Ion Accelerator Facility (HIAF)

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Outline

- Introduction
- HIAF and Its Physics
- Future Plan and EicC
HISTORY OF THE UNIVERSE

Big-Bang

QGP

Formation of Nuclei

Today Universe

Origin of Heavy Elements

Hot/Dense Matter
IMP Facilities History

Institute of Modern Physics (IMP)
Nuclear Physics Research Plan at IMP

Nuclear Structure

QCD Phase Structure

Nucleon Structure

CSR

CEE/HIAF

EicC
Lanzhou (HIRFL-CSR)

CEE: CSR External-target Experiment

1) Extreme high baryon density and low temperature region
2) Strong nucleonic interactions
High Intensity heavy-ion Accelerator Facility (HIAF)

- One of 16 large-scale research facilities proposed in China in order to boost basic science in 12th – 5 years plan (2011-2015)
- Approved was in December 2015. Budget: 1.5+1.1B CNY
- Now it is under technical design, will start construction in 2018
- Operation in 2024
BRing1: Booster ring 1
Circumference: 600 m
Rigidity: 34 Tm
Large acceptance (200/100)
Two planes painting injection
Fast ramping rate (5-10Hz)

BRing2: Booster ring 2
Circumference: 600 m
Rigidity: 86 Tm
Beam stacking
Super-conducting

Primary beam I vs: HIRFL: $10^3 - 10^4$
Secondary beam I vs: HIRFL: $10^4$

iLinac: Superconducting linac
Length: 100 m
Energy: 17~22 MeV/u (U^{35+} ~ U^{46+})

SECRAL and FECR
28-45GHz, 1.0emA (U^{35+})

SECRAL and FECR
28-45GHz, 1.0emA (U^{35+})

Low energy nuclear structure terminal
## HIAF Beam Parameters

<table>
<thead>
<tr>
<th>Source</th>
<th>Ions</th>
<th>Energy</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SECR</strong></td>
<td>$^{238}\text{U}^{35+\sim46+}$</td>
<td>14 keV/u</td>
<td>0.05-0.1 pmA</td>
</tr>
<tr>
<td><strong>iLinac</strong></td>
<td>$^{238}\text{U}^{35+\sim46+}$</td>
<td>17~22 MeV/u</td>
<td>0.028-0.05 pmA</td>
</tr>
<tr>
<td><strong>BRing1</strong></td>
<td>$^{238}\text{U}^{35+\sim46+}$</td>
<td>0.8~1.2 GeV/u</td>
<td>$2.0\times10^{11}$ ppp</td>
</tr>
<tr>
<td><strong>BRing2</strong></td>
<td>$^{238}\text{U}^{35+\sim46+}$</td>
<td>3~4.1 GeV/u</td>
<td>$\sim1.0\times10^{12}$ ppp</td>
</tr>
<tr>
<td></td>
<td>$^{238}\text{U}^{92+}$</td>
<td>3.8 GeV/u</td>
<td>$\sim5.0\times10^{11}$ ppp</td>
</tr>
<tr>
<td><strong>SRing</strong></td>
<td>RIBs: neutron-rich, proton-rich</td>
<td>0.84 GeV/u (A/q=3)</td>
<td>$\sim10^{9-10}$ ppp</td>
</tr>
<tr>
<td></td>
<td>Fully stripped heavy ions</td>
<td>0.8 GeV/u ($^{238}\text{U}^{92+}$)</td>
<td>$\sim10^{11-12}$ ppp</td>
</tr>
<tr>
<td></td>
<td>H-like, He-like heavy ions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The highest intensity pulsed heavy ion beam in the world

<table>
<thead>
<tr>
<th>Institute</th>
<th>Machine</th>
<th>Planned Intensity</th>
<th>Achieved Intensity</th>
<th>Ion species</th>
<th>Repetition rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>JINR</td>
<td>NICA Booster</td>
<td>$4 \times 10^9$</td>
<td></td>
<td>Au$^{32+}$</td>
<td></td>
</tr>
<tr>
<td>GSI</td>
<td>SIS18</td>
<td>$1.0 \times 10^{11}$</td>
<td>$3 \times 10^{10}$</td>
<td>U$^{28+}$</td>
<td>3Hz</td>
</tr>
<tr>
<td>FAIR</td>
<td>SIS100</td>
<td>$4.0 \times 10^{11}$</td>
<td></td>
<td>U$^{28+}$</td>
<td></td>
</tr>
<tr>
<td>IMP</td>
<td>HIAF-BRing1</td>
<td>$2.0 \times 10^{11}$</td>
<td></td>
<td>U$^{35+}$</td>
<td>5-10Hz, 10-20Hz</td>
</tr>
<tr>
<td>IMP</td>
<td>HIAF-BRing2</td>
<td>$1.0 \times 10^{12}$</td>
<td></td>
<td>U$^{35+}$</td>
<td></td>
</tr>
</tbody>
</table>
Physics Topics at HIAF

T1: Nuclear structure and reaction dynamics

T2: QCD phase structure at high baryon density

T3: QCD and Nucleon structure

T4: Applications
T1: The Origin of (heavy) Elements

- Study nuclear structure, origin of heavy elements
- To explore the limit of nuclear existence
- Provide necessary information for astrophysics
QCD phase structure and nucleon structure

- QCD is the basic theory for strong interaction
- QCD at short distance: is well defined
- QCD at long distance: little is known regarding the dynamical structures of matter, e.g. the confinement, nucleon structure, the QCD phases structure

CEE/HIAF: the QCD phase structure
EicC: nucleon structure and hadronization
T2: QCD Phase Structure

1. $T_{\text{init}}$, $T_C$
   - LHC, RHIC

2. $T_E$
   - RHIC, SPS

3. CP, Large $\mu_B$
   - FAIR, NICA, HIAF

Early Universe

Quark-gluon plasma

hadronic phase

Baryon Chemical Potential $\mu_B$ (MeV)

Temperature $T$ (MeV)

$T_C = 160 - 175$ MeV $\approx 2 \times 10^{12}$ K

Search for the QCD Critical Point

- RHIC BES-II: dramatically reduce the errors!
- CBM/RHIC FXT/CEE Experiments

Key region for Critical Point search

Hunt for QCD Critical Point!

√s_{NN} = 2 - 11\text{GeV}, \quad 800 \geq \mu_B \geq 300 \text{MeV}

America  \quad RHIC  \quad STAR (2019 - 2020)
Russia    \quad NICA  \quad MPD (2023)
Germany   \quad FAIR  \quad CBM (2025)
China     \quad HIAF  \quad CEE (2023)

Super Beam Energy Scan:  \quad sBES
HIAF Future Plan: EicC

- **EicC-I**: 2028-2035
  
suggest startup R&D for EicC during 2021-2025

Electron-Ion Collider at China: EicC
T3: EicC: nucleon structure

nucleon structure:
- spin of nucleon
- mass of nucleon
- role of gluons
- confinement
- exotic states
- …
EicC: the structure of the nucleon

Elastic scattering

Deeply Inelastic Scattering

Hard exclusive processes

Form factors

Nobel prize, 1961

Parton distributions

Nobel prize, 1969

Generalized Parton Distributions (GPDs)

Nobel prize, 1990

3D Partonic Image of Proton with the EIC
HIAF- EicC-I

EIC-I New construction
- polarization ion source
- Siberia snake for FRing
- e injector
- SRF Linac-ring
- 4~5 passes
- eRing
- 3~4A SR

Collider Ring (2 km):
- Up: Polarized electron, 10 GeV
- Down: Polarized proton, 60-100 GeV

Electron injector:
- SRF Linac-ring, 3.5-10 GeV

HERing
- 5-10 GeV
- C: 1.5-2.0 km

HPRing
- 60-100 GeV
- C: 1.5-2.0 km

EiC-I
- 20 GeV p + 3.5 GeV e
- $\sqrt{s} = 16.7$ GeV

EiC-II
- 60 GeV p + 5 GeV e
- $\sqrt{s} = 34.6$ GeV

Very preliminary!!
Machine Kinematics and Physics

Compare the kinematic ranges of EicC with JLab 12 GeV

Facilities

| JLab 12 GeV (FXT) | EicC-I ($\sqrt{s} \sim 15$ GeV) | EicC-II ($\sqrt{s} \sim 35$ GeV) |

Main goals

Valence quark

Valence and Sea quark

Sea quark and gluon
EicC Challenge and Detector

- Polarized electron and proton beam
- Interaction region or collision region design
- EIC detector design and construction (Forward tracking)

EicC Concept Detector

- ☑️ We have the technology
- ☐ Need international collaborators
HIAF Location

View of the HIAF campus
Summary

● HIAF will be one of the next-generation world leading heavy ion facility for advances in nuclear physics and applications

● EicC is the future plan for high-energy nuclear physics in China
  ➢ EicC physics programs complement the world efforts of EIC
  ➢ the working groups are preparing for the EicC whitepaper

● HIAF and EicC: open for the domestic and international collaborations
Thank You !